

## 7.5: Missions to the Moon

### 7.5.1 Early Lunar Missions

The first missions to the Moon began in 1958 as both the United States and the Soviet Union raced to one up each other. Many of the early missions ended in failure or partial success, but over time, both nations records improved. By the 1990s, other players, including Japan, ESA, China, and India began sending their own missions to the Moon as well. The table below summarizes the missions to the Moon from 1958 until the present.

<b>Spacecraft</b>	<b>Launch Date</b>	<b>Carrier</b>	<b>Mission Type</b>	<b>Result</b>
<i>Pioneer 0</i>	8/17/58	USAF	Orbiter	Launch failure
<i>Luna E-1 No. 1</i>	9/23/58	USSR	Impactor	Launch failure
<i>Pioneer 1</i>	10/11/58	NASA	Orbiter	Launch failure
<i>Luna E-1 No. 2</i>	10/11/58	USSR	Impactor	Launch failure
<i>Pioneer 2</i>	11/8/58	NASA	Orbiter	Launch failure
<i>Luna E-1 No. 3</i>	12/4/58	USSR	Impactor	Launch failure
<i>Pioneer 3</i>	12/6/58	NASA	Flyby	Launch failure
<i>Mechta (E-1 No. 4)</i>	1/2/59	USSR	Impactor	Launch failure
<i>Pioneer 4</i>	3/3/59	NASA	Flyby	Partial failure (first U. S. spacecraft to leave Earth orbit)
<i>E-1A No. 1</i>	6/18/59	USSR	Impactor	Launch failure
<i>Luna 2</i>	9/12/59	USSR	Impactor	Successful (first spacecraft to reach the lunar surface)
<i>Luna 3</i>	10/4/59	USSR	Flyby	Successful (returned first images of the far side of the Moon)
<i>Pioneer P-3</i>	11/26/59	NASA	Orbiter	Launch failure
<i>Luna E-3 No. 1</i>	4/15/60	USSR	Flyby	Launch failure
<i>Luna E-3 No. 2</i>	4/16/60	USSR	Flyby	Launch failure
<i>Pioneer P-30</i>	9/25/60	NASA	Orbiter	Launch failure
<i>Pioneer P-31</i>	12/15/60	NASA	Orbiter	Launch failure
<i>Ranger 3</i>	1/26/62	NASA	Impactor	Spacecraft failure
<i>Ranger 4</i>	4/23/62	NASA	Impactor	Spacecraft failure
<i>Ranger 5</i>	10/18/62	NASA	Impactor	Spacecraft failure
<i>Luna E-6 No. 2</i>	1/4/63	USSR	Lander	Launch failure
<i>Luna E-6 No. 3</i>	2/3/63	USSR	Lander	Launch failure

<i>Luna 4</i>	4/2/63	USSR	Lander	Spacecraft failure
<i>Ranger 6</i>	1/30/64	NASA	Impactor	Spacecraft failure
<i>Luna E-6 No. 6</i>	3/21/64	USSR	Lander	Launch failure
<i>Luna E-6 No. 5</i>	4/20/64	USSR	Lander	Launch failure
<i>Ranger 7</i>	7/28/64	NASA	Impactor	Successful (Impacted on 7/30/64)
<i>Ranger 8</i>	2/17/65	NASA	Impactor	Successful (Impacted on 2/20/65)
<i>Kosmos 60</i>	3/12/65	USSR	Lander	Launch failure
<i>Ranger 9</i>	3/21/65	NASA	Impactor	Successful (Impacted on 3/24/65)
<i>Luna E-6 No. 8</i>	4/19/65	USSR	Lander	Launch failure
<i>Luna 5</i>	5/9/65	USSR	Lander	Spacecraft failure
<i>Luna 6</i>	6/8/65	USSR	Lander	Spacecraft failure
<i>Zond 3</i>	7/8/65	USSR	Flyby	Successful
<i>Luna 7</i>	10/4/65	USSR	Lander	Spacecraft failure
<i>Luna 8</i>	12/3/65	USSR	Lander	Spacecraft failure
<i>Luna 9</i>	1/31/66	USSR	Lander	Successful (first spacecraft to successfully land on the Moon. Landed on 2/3/66 and returned data until 2/6/66)
<i>Kosmos 111</i>	3/1/66	USSR	Orbiter	Launch failure
<i>Luna 10</i>	3/31/66	USSR	Orbiter	Successful (first spacecraft to orbit the Moon)
<i>Surveyor 1</i>	5/30/66	NASA	Lander	Successful (landed on 6/2/66 and returned data until 7.13.66)
<i>Explorer 33</i>	7/1/66	NASA	Orbiter	Launch failure
<i>Lunar Orbiter 1</i>	8/10/66	NASA	Orbiter	Partial failure (deorbited early due to lack of fuel)
<i>Luna 11</i>	8/21/66	USSR	Orbiter	Partial failure (Entered orbit but failed to return images)
<i>Surveyor 2</i>	9/20/66	NASA	Lander	Spacecraft failure
<i>Luna 12</i>	10/22/66	USSR	Orbiter	Successful
<i>Lunar Orbiter 2</i>	11/6/66	NASA	Orbiter	Successful
<i>Luna 13</i>	12/21/66	USSR	Lander	Successful
<i>Lunar Orbiter 3</i>	2/5/67	NASA	Orbiter	Successful

<i>Surveyor 3</i>	4/17/67	NASA	Lander	Successful (Landed on 4/20/67 and returned data until 5/3/67)
<i>Lunar Orbiter 4</i>	5/4/67	NASA	Orbiter	Successful
<i>Surveyor 4</i>	7/14/67	NASA	Lander	Spacecraft failure
<i>Explorer 35</i>	7/19/67	NASA	Orbiter	Successful
<i>Lunar Orbiter 5</i>	8/1/67	NASA	Orbiter	Successful
<i>Surveyor 5</i>	9/8/67	NASA	Lander	Successful
<i>Soyuz 7K-L1 No. 4L</i>	9/27/67	USSR	Flyby	Launch failure
<i>Surveyor 6</i>	11/7/67	NASA	Lander	Successful
<i>Soyuz 7K-L1 No.5L</i>	11/22/67	USSR	Flyby	Launch failure
<i>Surveyor 7</i>	1/7/68	NASA	Lander	Successful
<i>Luna E-6LS No. 112</i>	2/7/68	USSR	Orbiter	Launch failure
<i>Luna 14</i>	4/7/68	USSR	Orbiter	Successful
<i>Soyuz 7K-L1 No. 7L</i>	4/22/68	USSR	Flyby	Launch failure
<i>Zond 5</i>	8/14/68	USSR	Flyboy	Successful
<i>Zond 6</i>	11/10/68	USSR	Flyby	Spacecraft failure
<i>Soyuz 7K-Li No. 13L</i>	1/20/69	USSR	Flyby	Launch failure
<i>Luna E-8 No. 201</i>	2/19/69	USSR	Lander/rover	Launch failure
<i>Soyuz 7K-L1S No. 3</i>	2/21/69	USSR	Orbiter	Launch failure
<i>Luna E-8-5 No. 402</i>	6/14/69	USSR	Lander, Sample return	Launch failure
<i>Soyuz 7K-L1S No. 5</i>	7/3/69	USSR	Orbiter	Launch failure
<i>Luna 15</i>	7/13/69	USSR	Lander, Sample return	Spacecraft failure
<i>Zond 7</i>	8/7/69	USSR	Flyby	Successful
<i>Kosmos 300</i>	9/23/69	USSR	Lander, Sample return	Launch failure
<i>Kosmos 305</i>	10/22/69	USSR	Lander, Sample return	Launch failure
<i>Luna E-8-5 No. 405</i>	2/6/70	USSR	Lander, Sample return	Launch failure
<i>Luna 16</i>	9/12/70	USSR	Lander, Sample return	Successful

<i>Zond 8</i>	10/20/70	USSR	Flyby	Successful
<i>Luna 17</i>	11/10/70	USSR	Lander/rover	Successful
<i>PFS-1</i>	7/26/71	NASA	Orbiter	Successful
<i>Luna 18</i>	9/2/71	USSR	Lander, Sample return	Spacecraft failure
<i>Luna 19</i>	9/28/71	USSR	Orbiter	Successful
<i>Luna 20</i>	2/14/72	USSR	Lander, Sample return	Successful
<i>PFS-2</i>	4/16/72	NASA	Orbiter	Successful
<i>Soyuz 7K-LOK No. 1</i>	7/3/72	USSR	Orbiter	Launch failure
<i>Luna 21</i>	1/8/73	USSR	Lander/rover	Successful
<i>Explorer 49</i>	6/10/73	NASA	Orbiter	Successful
<i>Mariner 10</i>	11/3/73	NASA	Flyby	Successful
<i>Luna 22</i>	5/29/74	USSR	Orbiter	Successful
<i>Luna 23</i>	10/28/74	USSR	Lander/Sample return	Spacecraft failure
<i>Luna E-8-5M No. 412</i>	10/16/75	USSR	Lander/Sample return	Launch failure
<i>Luna 24</i>	8/9/74	USSR	Lander/Sample return	Successful
<i>ISEE-3</i>	8/12/78	NASA	Gravity Assist en route to Comet 21P/Giacobini–Zinner.	Successful
<i>Hiten</i>	1/24/90	ISAS (Japan)	Flyby/Orbiter	Successful
<i>Hagoromo</i>	1/24/90	ISAS	Orbiter	Spacecraft failure (Deployed from Hiten)
<i>Geotail</i>	7/24/92	ISAS/NASA	Gravity assist	Successful
<i>WIND</i>	11/1/94	NASA	Gravity assist to reach Earth-Sun L1 point	Successful
<i>Clementine</i>	1/25/94	USAF/NASA	Orbiter	Successful
<i>Lunar Prospector</i>	1/7/98	NASA	Orbiter	Successful, confirmed ice in one of Moon's polar craters
<i>Nozomi</i>	7/3/98	ISAS	Gravity assist	Spacecraft failure

WMAP	6/30/01	NASA	Gravity assist to reach Earth-Sun L2 point	Successful
SMART-1	9/27/03	ESA (European Space Agency)	Orbiter	Successful
STEREO A	10/25/06	NASA	Gravity Assist to reach heliocentric orbit	Successful
STEREO B	10/25/06	NASA	Gravity Assist to reach heliocentric orbit	Successful
ARTEMIS P1	2/17/07	NASA	Orbiter	Successful, still operational
ARTEMIS P2	2/17/07	NASA	Orbiter	Successful, still operational
SELENE	9/14/07	JAXA (Japan)	Orbiter	Successful
Chang'e 1	10/24/07	China	Orbiter	Successful
Chandrayaan-1	10/28/08	India	Orbiter	Successful
Moon Impact Probe	10/22/08	India	Impactor	Successful
Lunar Reconnaissance Orbiter	6/8/09	NASA	Orbiter	Successful, still operational
LCROSS	6/8/09	NASA	Impactor	Successful
Chang'e 2	10/1/10	China	Orbiter	Successful
Ebb (GRAIL-A)	9/10/11	NASA	Orbiter	Successful
Flow (GRAIL-B)	9/10/11	NASA	Orbiter	Successful
LADEE	9/7/13	NASA	Orbiter	Successful
Chang'e 3	12/1/13	China	Lander	Successful, still operational
Yutu	12/1/13	China	Rover	Mostly successful, deployed from Chang'e 3
Chang'e 5-T1	10/23/14	China	Flyby	Successful
Manfred Memorial Moon Mission	10/23/14	LuxSpace (private European agency)	Flyby	Successful
TESS	4/18/18	NASA	Gravity assist into high Earth orbit	Successful

<i>Queqiao</i>	5/21/18	China	Gravity assist to L5 orbiter	Successful, still operational
<i>Longjiang-1</i>	5/21/18	China	Orbiter	Spacecraft failure
<i>Longjiang-2</i>	5/21/18	China	Orbiter	Successful
<i>Chang'e 4</i>	12/7/18	China	Lander	Successful, still operational
<i>Yutu-2</i>	12/7/18	China	Rover	Successful, still operational, deployed from Chang'e 4
<i>Beresheet</i>	2/19/19	Israel	Lander	Spacecraft landing failure
<i>Chandrayaan-2</i>	7/22/19	India	Orbiter	Successful, still operational
<i>Vikram/Pragyan</i>	7/22/19	India	Lander/rover	Lander failure

Throughout the 1960s and 1970s, both NASA and the USSR often followed a policy of launching missions in pairs, launching two probes within a few weeks of each other. This doubled the chances of success in the case one of the probes failed. A launch failure meant a malfunction in the one of the stages of the launch vehicle, resulting in the probe failing to reach orbit. A spacecraft failure meant a malfunction in the probe itself, usually resulting in the craft failing to achieve orbit, crashing on the surface, or otherwise not being able to complete its mission. The peculiar naming convention of many of the USSR's lunar missions stems in part from the Soviet policy of restarting numbering or renaming missions to "erase" their failures.

Note the gap in between 1978 and 1990 when no country launched any lunar missions as both the Soviets and America focused their resources on other projects.

Some highlights of the early days of lunar exploration include:

- The Luna 1 Impactor (USSR) was the first successful flyby of the Moon and demonstrated that the Moon had no magnetic field. It was supposed to impact the Moon, but a malfunction caused it to miss.
- Pioneer 4 (NASA) made a partial successful flyby of the Moon at 60,000 km.
- Luna 3 Flyby (USSR) transmitted the first pictures of the far side of the Moon.
- NASA's Ranger 3 was supposed to be an impactor but made a flyby instead while Ranger 4 crashed on the far side without returning any data.
- Luna 9 (USSR) became the first successful lander on the Moon.
- Zond 5 contained the first "Earthlings" to flyby the Moon: Two tortoises, some mealworms, wine flies, and plants
- Zond 6 carried a similar payload of organisms, but a depressurization accident killed the biologicals.
- Mariner 10 also took pictures of the Moon on its way to Venus and Mercury.
- While NASA focused on the manned Apollo missions, the Soviets performed robotic sample return missions, the last one being Luna 24 in 1974.

### 7.5.2 Apollo Missions



Of course, the Apollo landings were the main attraction of the lunar missions of the late 1960s and early 1970s. Following Kennedy's 1961 challenge, NASA threw considerable resources toward meeting his deadline of the end of the 1960s. Unfortunately, the program began with some serious problems. Apollo 1 caught fire on the launch pad during an engine test, killing all three astronauts on board: Gus Grissom, Ed White, and Roger Chaffee. A post-accident review found several design flaws. In future missions, the 100% oxygen atmosphere inside the cabin was replaced with normal breathing air. NASA also redesigned the spacesuits to be fire resistant and made the hatch easier to open in the event of an abort. Because of these changes, NASA scrapped Apollo 2 and 3. They tested the Saturn V rocket with an unmanned capsule for Apollo 4. NASA used Apollo 5 as an unmanned test of the Saturn IB rocket. Apollo 5 was also the first to carry the **lunar module (LM)**, the vehicle that eventually landed on the Moon. Apollo 6 used the Saturn V rocket to test the **Command/Service Module (CSM)** which would orbit the Moon while the LM was on the surface.

Apollo 7 was the first manned flight and performed an 11-day Earth orbit to test the CSM systems. Apollo 8, crewed by Jim Lovell, Frank Borman, and William Anders became the first manned vehicle to orbit the Moon. NASA used Apollo 9 to test the full lunar EVA suit and its portable life systems. Then, Apollo 10 took the LM within 50,000 feet of the Lunar surface.

Finally, on July 20, 1969, Apollo 11 landed on the Moon! Neil Armstrong and Buzz Aldrin took the LM to the surface while Michael Collins remained in the CSM in orbit.



The Apollo 11 landing module.

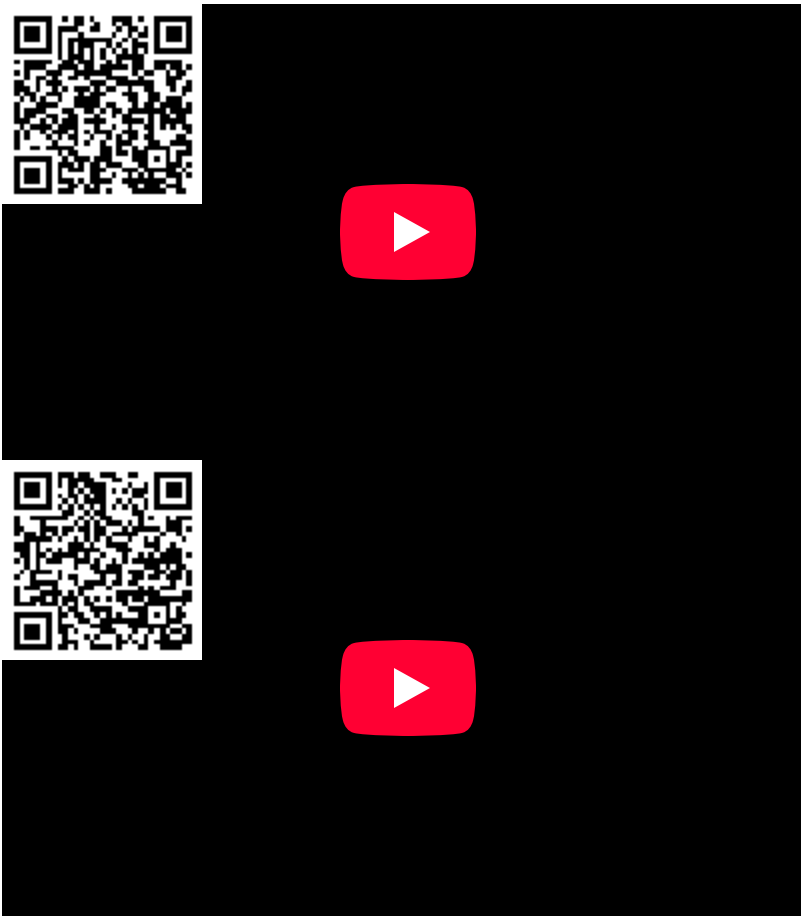
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The official crew portrait of the Apollo 11 astronauts from left to right are: Neil A. Armstrong, Commander; Michael Collins, Module Pilot; Edwin E. "Buzz" Aldrin, Lunar Module Pilot

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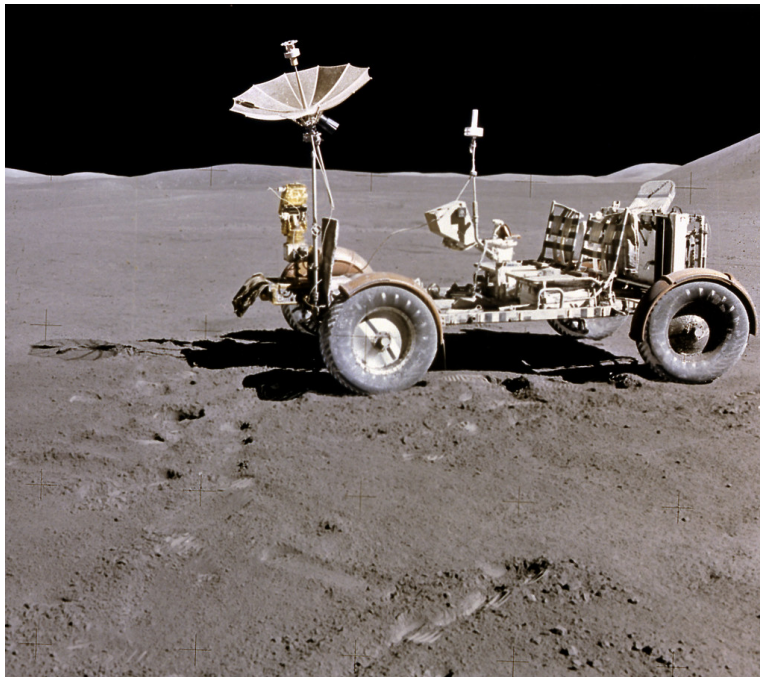




Apollo 12 landed within walking distance of Surveyor 3's landing site and returned with some parts from it.

Apollo 13 became known as the "successful failure." A mechanical failure prevented them from landing on the Moon and only performed a flyby before returning to Earth. All three astronauts, Jim Lovell, Jack Swigert, and Fred Haise all returned to Earth safely.

Apollo 14-17 were all successful with Apollo 15-17 being the missions that used the Lunar Rover to explore the surface. Apollo 17 landed on the Moon on December, 1972 and became the last Apollo mission. Indeed, it was the last time any human has traveled beyond Low Earth Orbit (LEO). Originally, at least two more Apollo missions had been planned. Nixon decided the costs of the remaining missions outweighed the benefits and scrapped the program to focus on the shuttle and other programs.



One of the lunar rovers used in the Apollo 14-17 missions.

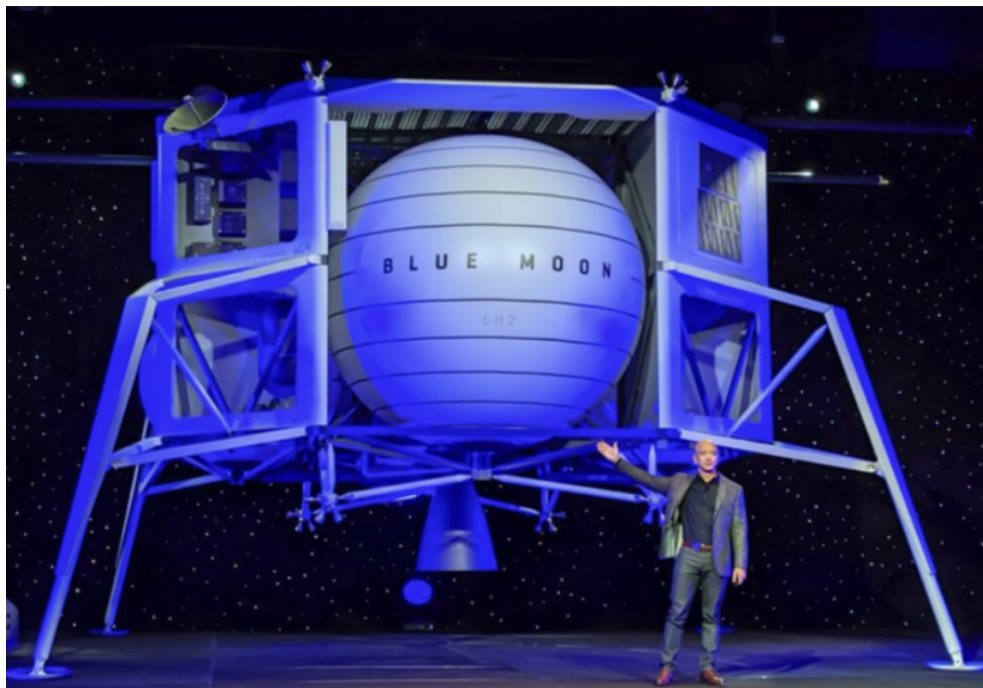
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### 7.5.3 Post-Apollo Moon Missions

Since the Golden Age of space travel, NASA and other organizations resumed lunar missions in the 1990s. Some recent highlights include:

- 1990: Japan launches the Hiten orbiter/impactor (above), making it the first Asian object to land on the moon.
- 1998: NASA launched the Lunar Prospector and in January 1999, the Lunar Prospector was deliberately crashed in the Moon's south pole, where it detected ice in one of its craters.
- 2014: LuxSpace launched the first private commercial probe of the Moon.
- Some orbiters and landers, including NASA's Lunar Reconnaissance Orbiter (LRO, China's Chang'e 4 and Yutu-2 lander/rover probes, and India's Chandrayaan-2 orbiter continue to operate today.



Mock up of Blue Origin's lunar lander that may one day take people and supplies to the surface of the Moon.

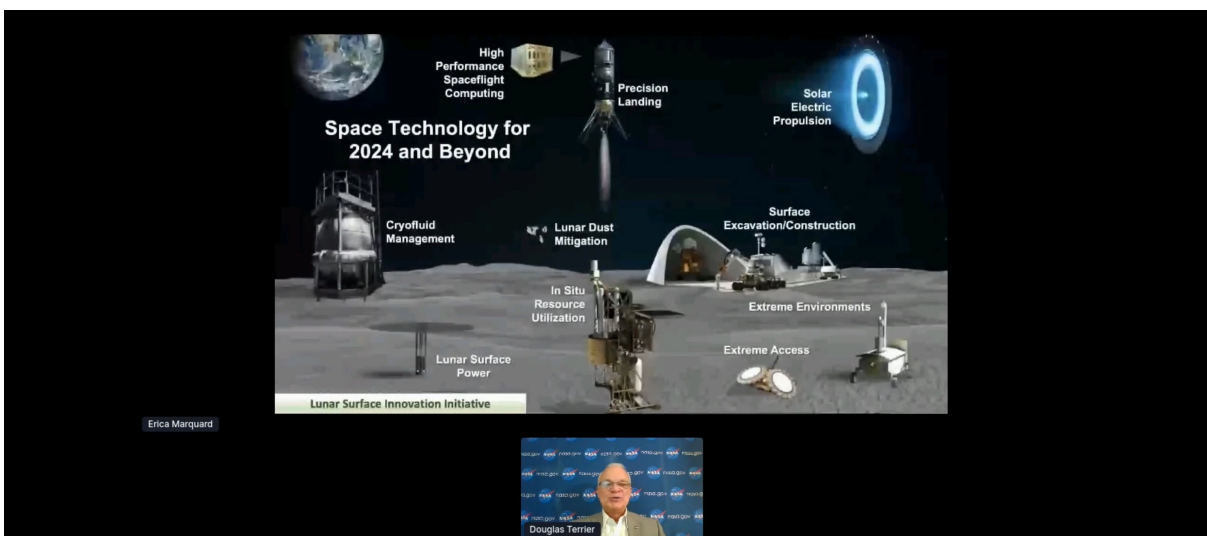
<https://commons.wikimedia.org/wiki/File:Spacecraft.png>

Even since the end of the Apollo missions, many have asked the question, when are we going back to the Moon? After many false starts, NASA is once again preparing for a return to the Moon with the Artemis program. With a target date for a human landing on the Moon in 2024, Artemis will be substantially different from Apollo. Instead of single missions, NASA intends to establish long-term missions on the Moon and in orbit around it. Private contractors will deliver robots and other materials to the Moon while NASA will use its SLS and Orion capsule to send astronauts to Gateway, a platform to be placed in orbit around the Moon. NASA has chosen three contractors, SpaceX, Blue Origin, and Dynetics to develop reusable landers to take astronauts to the surface. Research conducted on the surface of the Moon and on-board Gateway will help prepare NASA for crewed missions to Mars and beyond. More than fifty years after the last Apollo landing, we may be going back to the Moon very soon.



NASA is developing the Orion capsule to carry astronauts to the Moon and possibly Mars.

[https://commons.wikimedia.org/wiki/File:Orion\\_capsule\\_at\\_KSC.JPG](https://commons.wikimedia.org/wiki/File:Orion_capsule_at_KSC.JPG);



NASA's plans to return to the Moon in the 2020s.

[https://www.nasa.gov/sites/default/files/thumbnails/image/dt\\_wt20\\_4\\_0.jpg](https://www.nasa.gov/sites/default/files/thumbnails/image/dt_wt20_4_0.jpg);





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